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The mineral composition and spatial distribution of the dust ejecta of NGC 6302 Based on observations with ISO, an ESA project with instruments funded by ESA Member States (especially the PI countries: France, Germany, the Netherlands and the United Kingdom) and with the participation of ISAS and NASA Based on observations made with ESO Telescopes at the La Silla or Paranal Observatories under programme ID 67.D-0132(A)

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F. Kemper et al. The mineralogy of NGC 6302

We have analysed the full ISO spectrum of the planetary nebula NGC 6302 in order to derive the mineralogical composition of the dust in the nebula. We use an optically thin dust model in combination with laboratory measurements of cosmic dust analogues. We find two main temperature components at about 100 and 50 K respectively, with distinctly different dust compositions. The warm component contains an important contribution from dust without strong infrared resonances. In particular the presence of small warm amorphous silicate grains can be excluded. The detection of weak PAH bands also points to a peculiar chemical composition of the dust in this oxygen-rich nebula. The cool dust component contains the bulk of the mass and shows strong emission from crystalline silicates, which contain about 10 percent of the mass. In addition, we identify the 92 μm band with the mineral calcite, and argue that the 60 μm band contains a contribution from the carbonate dolomite. We present the mass absorption coefficients of six different carbonate minerals. The geometry of the dust shell around NGC 6302 is studied with mid-infrared images obtained with TIMMI2. We argue that the cool dust component is present in a circumstellar dust torus, while the diffuse emission from the warm component originates from the lobes. planetary nebulae: individual: NGC 6302 – stars: circumstellar matter – dust, extinction – methods: laboratory

Introduction sec:intro

All low and intermediate mass stars end their life on the Asymptotic Giant Branch (AGB) by ejecting their entire H-rich envelope through a slowly expanding, dusty wind. After the AGB, the central star quickly increases its effective temperature to values high enough to begin ionizing its AGB ejecta: a planetary nebula (PN) is born. Depending on the mass and thus luminosity of the star, the transition from AGB to PN can go very fast: for the most massive objects, in less than 1000 years ionization of the nebula begins. These massive objects therefore are characterized by dense AGB remnants and a very hot luminous central star.

NGC 6302 is probably one of the best studied PNe with a massive progenitor. A recent determination of the mass of the ionized nebula is about 2 $M_\odot$ PB$_9 9_N GC6302, basedonadistancedeterminationof 1.6 kpc GRM_9 3_n gc6302. Dustr$
0.02 $M_\odot$), using a distance of 2.2 kpc GMR$_8 9_N GC6302. ThesedistancedeterminationsrelyonVLAobservationsoftheexpansio$
In principle, this is a very reliable method, however the epoch over which the nebula is observed, is very short. Therefore the increase in size is very small and hard to measure, indicating that the error bars on these distance determinations are still very large. Instead, we adopt a distance of 0.91 kpc, based on emission-line photometry of NGC 6302, from which the B and V magnitudes, the luminosity and the distance can be derived SK$_8 9_P Ne. ThelargenumberofluminousPNestudiedgivesconfidenceinthedistancedeterminationfromthisstatisticalmetho$

The nebular abundances indicate that NGC 6302 is a type I nebula, consistent with a massive progenitor. CRB$_0 0_n gc6302_n gc6537 estimatethattheprogenitormassis 4--5M_\odot$. The morphology of the nebula observed at optical wavelengths is highly bipolar, pointing to non-spherical mass loss on the AGB, resulting in a dusty torus in the equatorial region LD$_8 4_n gc6302. Theinclinationangleofthesystemis \sim 45^o$ with respect to the line-of-sight B$_9 4_n gc6302. Thetemperatureofthecentralstarisveryhigh : CRB_0 0_n gc6302_n gc6537 mentionatemperatureof \sim$
250 000 K, while PBD$_9 6_c entralstararriveatemperatureof \sim$ 380 000 K. Although there is some uncertainty about the distance and therefore masses and luminosities involved, everything points to a rather massive and luminous progenitor.

The Infrared Space Observatory (ISO) spectrum has been presented in several papers B$_9 8_L WS_A GB, MLS_0 1_N GC6302, M$

-70μm spectral range caused by circumstellar dust in the AGB remnant, as well as by strong emission lines from a multitude of fine-structure lines originating from the ionized gas in the nebula. The dust bands have been identified with crystalline silicates and a number of other components KTS$_0$0$_d iopside, MLS_01_NGC6302, MWT_02_xsilII.[$
and $\sim$92 μm.

Optical and near-infrared images have already shown that the dust distribution around NGC 6302 is rather complex LD$_8$4$_n gc6302, SCM_92_PNimages.TheISOspectroscopysupportsthis, becauseabroaddusttemperaturerangeis$
$richdustandcarbon-richdustfeatures, thelatterintheformPolycyclicAromaticHydrocarbons(PAHs)(seeMLS_01_NGC6302$

In order to reconstruct the mass loss history of NGC 6302, including the geometry and composition of the AGB wind, infrared spectroscopy and imaging are needed. Unfortunately, the ISO data lack spatial information, limiting the analysis to the bulk dust composition. Mid-infrared imaging can reveal the present-day geometry of the dust envelope, which puts limits on the mass loss history.

This paper is organized as follows: In Sect. sec:TIMMI2 the ground-based mid-infrared imaging and spectroscopy is presented. The ISO spectroscopy is discussed in Sect. sec:ISO, which describes our laboratory data of carbonates (Sect. sec:carbonates) and a model fit to the observed spectrum (Sect. sec:modelfit). In Sect. sec:discussion we propose a possible geometry of NGC 6302 and discuss the astronomical relevance of carbonates. Our results are summarized in Sect. sec:summary.

The TIMMI2 observations sec:TIMMI2

N- and Q-band imaging sec:nqimag

We have observed NGC 6302 using the TIMMI2 mid-infrared imaging spectrograph attached to the 3.6m telescope at the European Southern Observatory, La Silla, Chile. For a description of the instrument see RLW$_0$0$_T IMMI2.Theobservationswerecarriedoutonthenightof June17/18, 2001.Observingconditionswerenotoptimal, with$
In addition, we obtained two 8.35-11.55 μm long-slit spectra. We observed HD 81797 and HD 169916 as point sources in order to determine the shape of the point spread function, as well as for flux calibration purposes, which is only performed in case of spectroscopy.

To correct for background, chopping and nodding has been performed. Apart from the Q-band image, the chopping and nodding images fell all inside the frame. For the various N-band images we used a lens scale corresponding to a pixel size of 0.3$''$/pixel, whereas the Q-band image was obtained with a pixel size of 0.2$''$/pixel. The dimensions of the detector are 320$\times$240 pixels of which the central 300$\times$220 pixels were used for further analysis. The chop throw used for the images in the N-band is 30$''$, with a nodding offset of 30$''$ perpendicular on the chop direction. For the Q-band image, we applied a chop throw of 40$''$, and a nodding offset of 40$''$ in the same direction as the chop.

Both the positive and negative images were used for the resulting image. The final image has been sharpened by means of a deconvolution using the point spread function (PSF) derived from HD 81797 for the Q-band. Unfortunately, for the N2, 10.4 and 11.9 filters no standard star was measured in the same night with the same settings, and we used observations of standards of another night. For the N2 and 10.4 filters no standards were available at all. Therefore, we used HD 169916 measured with the 11.9 μm filter for all three filters for the PSF, assuming that the PSF would be similar in all three N-bands. A comparison with other N2-band images (with different settings, but the positive and negative images did overlap each other) showed that our assumption is not unreasonable.

figure* [width=12cm]H3717F1.eps []TIMMI2 images of NGC 6302. In the upper left corner the VLT-first light image of NGC 6302 is shown ESO$_9$8$_V LTfirstlight.Theuppermiddleimageisthelogarithmicnon-$
$deconvolvedN2bandimage, whichshowsthelowbrightnessstructuresomewhatbetterthanthedeconvolvedimages.Intheupperr$
$bandimages.Allimageshavethesameorientationandscale.fig:TIMMI2$